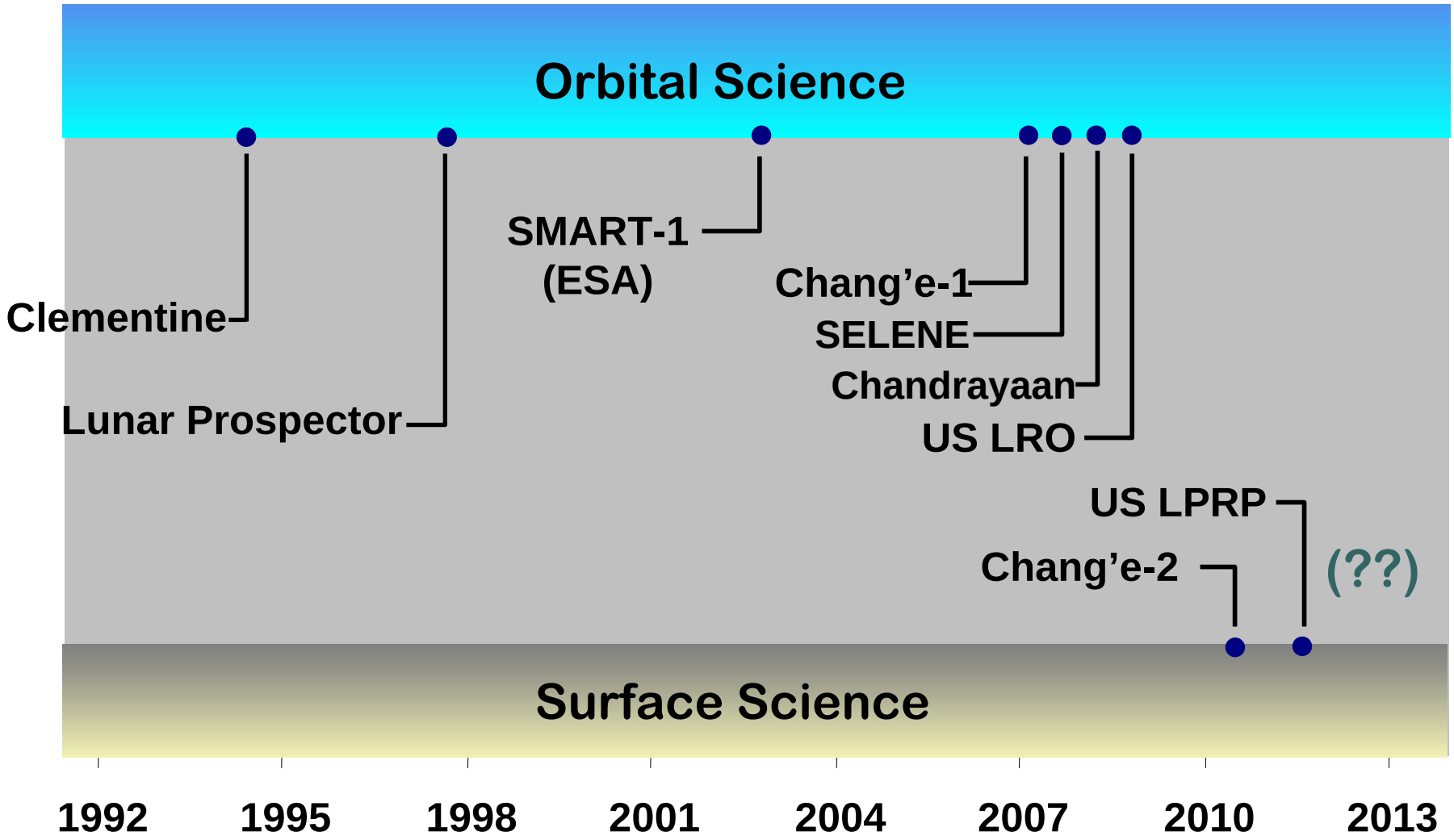
Lunar Missions, 1992-2014



ESA SMART-1

ESA SMART-1 Orbiter, ongoing

Launched: 27 September 2003

Status: Arrived in lunar orbit, 15 November 2004. Nominal mission: 2-2.3 yrs.

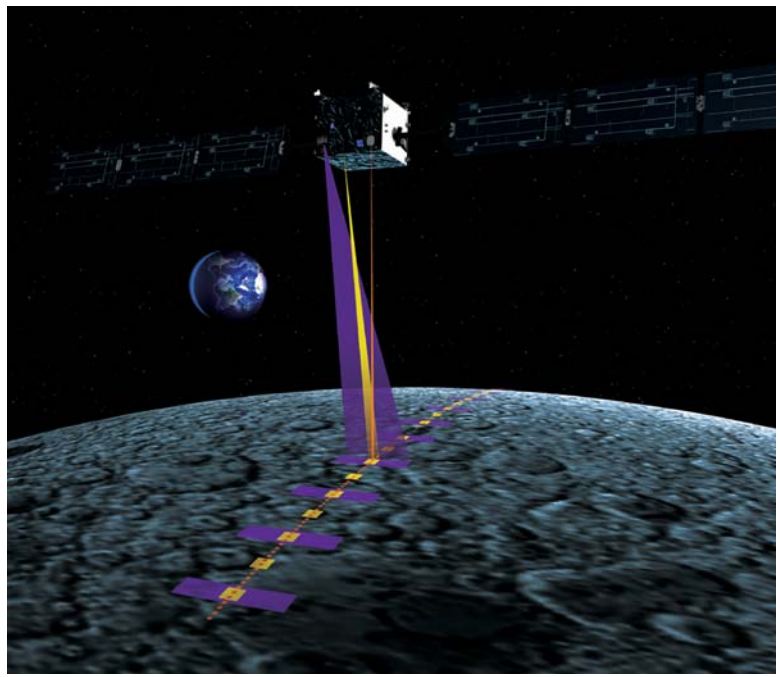
Technology Demonstration:

- Solar-electric Ion-propulsion
- Laser communications

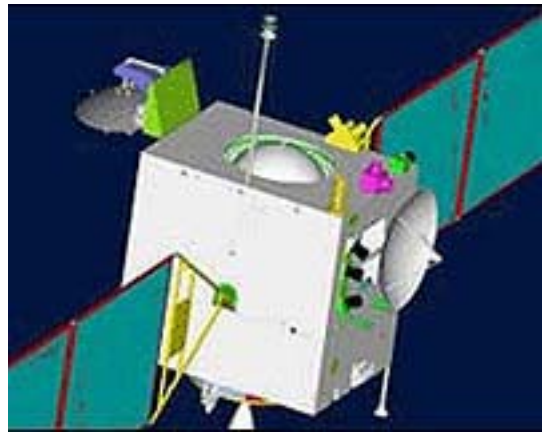
Science Instruments:

- X-ray spectrometer (D-CIXS)
- VIS-NIR Camera (AMIE)
- Infrared Spectrometer (SIR)
- Radio Experiment (RSIS)

Will complete mission by attempting a controlled low-angle impact into a permanently shadowed crater.



Chang'E-1



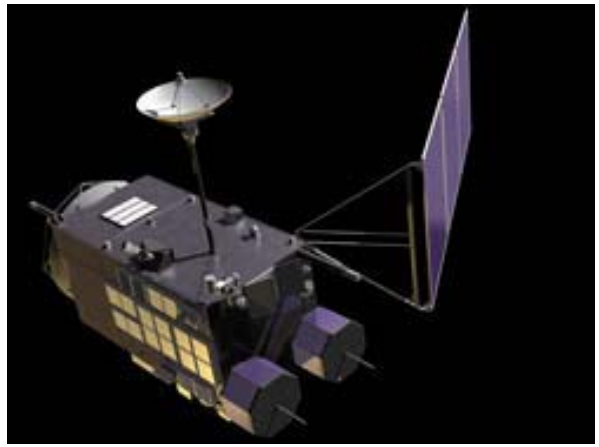
- The orbiter, based on China's Dongfanghong III satellite platform, will be launched on a Long March 3-A rocket.
- The spacecraft will be tested at the space launch center in December. If tests go well, orbiter will be launched in April 2007.
- China's lunar probe project will be divided into three phases:
  - (1) satellite to orbit Moon by 2007
  - (2) landing an unmanned vehicle on the moon by 2010,
  - (3) collecting samples of lunar soil with an unmanned vehicle by 2020.
- The Spacecraft weighs 1000 kg and carries 5 instruments

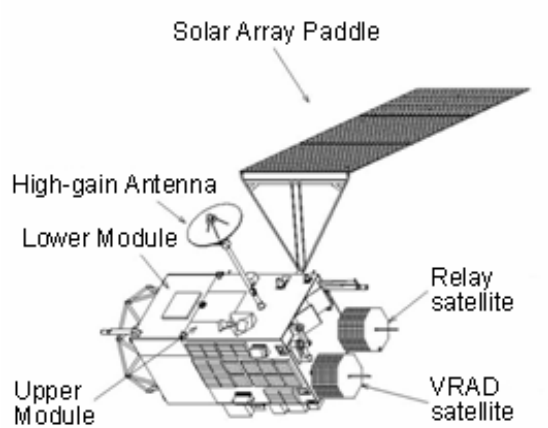
Chang'E-1 Payload

- Altimeter: topography
- Stereo Camera
- Gamma ray spectrometer: determine radioactivity of lunar surface
- X-ray spectrometer: determine composition of lunar surface
- Microwave Radiometer: determine thickness of lunar regolith
- Space environment monitor system: Map solar wind
- Solar high-energy particles and solar wind ion detector

SELENE

- SELENE (SELenological and ENgineering Explorer) is targeting launch in summer of 2007 on an H-IIA rocket.
- Nominal mission is 1 year in orbit.
- Mapping orbit will be 100 km altitude, circular, 3-axis stabilized.
- Expected data volume: ~10 Terabytes
- Data access: 1 year after end of nominal mission; planning for PDS compliant data formats
- Spacecraft mass: 2885 Kg (wet)





SELENE Instrument suite (1)

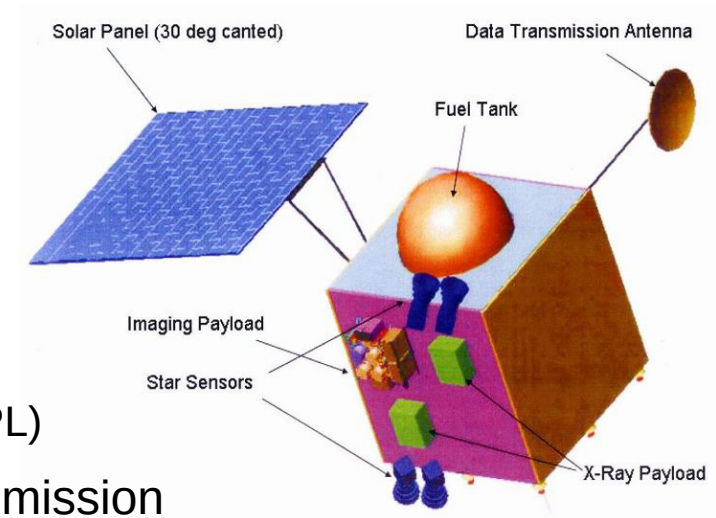
	Observation	Instrument and Characteristics
Main Orbiter	Chemical distribution	X-ray Spectrometer [XRS] (Surface distribution of major elements such as Mg, AI, Si, Fe, Na using X-ray CCD array, with spatial resolution of 20km) Gamma-ray Spectrometer [GRS] (Global mapping of K, U, Th etc. distributions using a highly pure Ge crystal, resolution 120km)
	Mineralogical distribution	Spectral Profiler [SP] (Continuous spectral profiling from 0.5 to 2.6μm, (Spectral resolution 6 to 8nm), spatial resolution 500m) Multiband Imager [MI] (UV-VIS-NIR imager, spectral coverage ranging from 0.4 to 1.6μm, 9 bands(Spectral resolution 20 to 50nm), spatial resolution 20m)
	Surface Structure	Terrain Camera [TC] (High-resolution stereo camera, spatial resolution 10m) Lunar Radar Sounder [LRS] (HF radar sounding of subsurface structure of the Moon and observation of natural radio and plasma waves) Laser Altimeter [LALT] (Nd:YAG laser altimeter, height resolution 5m, pulse rate 1Hz)

SELENE Instrument suite (2)

	Observation	Instrument and Characteristics
Main Orbiter	Surface environment & Imaging	Lunar Magnetometer[LMAG] (Mag. field measurement w/ flux-gate magnetometers, accuracy 0.5 nT) Upper atmosphere and Plasma Imager[UPI] (Imaging of the Earth's magnetosphere and aurora from lunar orbit) Charged Particle Spectrometer[CPS] (Mapping Rn and Po using the ARD(4 to 6.5 MeV for alpha), Measurement of high energy particles using the PS instruments (e: 0.3 to 1MeV, p:0.1 to 60MeV, Heavy ion: 2.5 to 370MeV/n)) Plasma energy Angle and Composition Experiment[PACE] (Charged particle energy and composition measurement 5eV/q to 28keV/q(Ion),5eV to 17keV(Electron)) Radio Science[RS] (Detection of lunar ionosphere using S- and X-band carriers)
	Imaging	High Definition Television [HDTV] (Photos and movies of the Earth and the Moon)
Relay satellite	Gravitational field distribution	Four way Doppler measurements by relay satellite and main orbiter transponder[RSAT-1,2] (Far-side gravity using four-way Doppler measurement from the ground station to Orbiter via Relay Satellite, 2400 x 100 km alt., elliptical orbit)
VRAD satellite **Relay satellite**	Gravitational field distribution	Differential VLBI Radio source-1,2[VRAD-1,2] (Differential VLBI observation of radio sources on Relay Satellite and VRAD Satellite from ground radio telescopes. 100 x 800 km, alt, elliptical)

Chandrayaan-1

- Indian Space Research Organization (ISRO) plans to launch Chandrayaan-1 in late 2007 or early 2008.
- The 1,157-lb. Chandrayan-1 will launch on one of India's Polar Satellite Launch Vehicle (PSLV) space rockets.
- Initially the spacecraft will circle Earth in a geosynchronous transfer orbit (GTO). From there, it will transit to a polar orbit of the Moon at an altitude of ~100 km above the lunar surface.
- Instruments will include:
  - XRF (ESA CIXS)
  - Gamma ray spectrometer
  - M3 (Moon Mineralogy Mapper, Brown/JPL)
  - Laser altimeter
  - Miniature synthetic aperture radar (APL)



- Chandrayaan is nominally a two-year mission
- Chandrayaan is Hindi for "Moon Craft"

Chandrayaan-1 Payload, detail

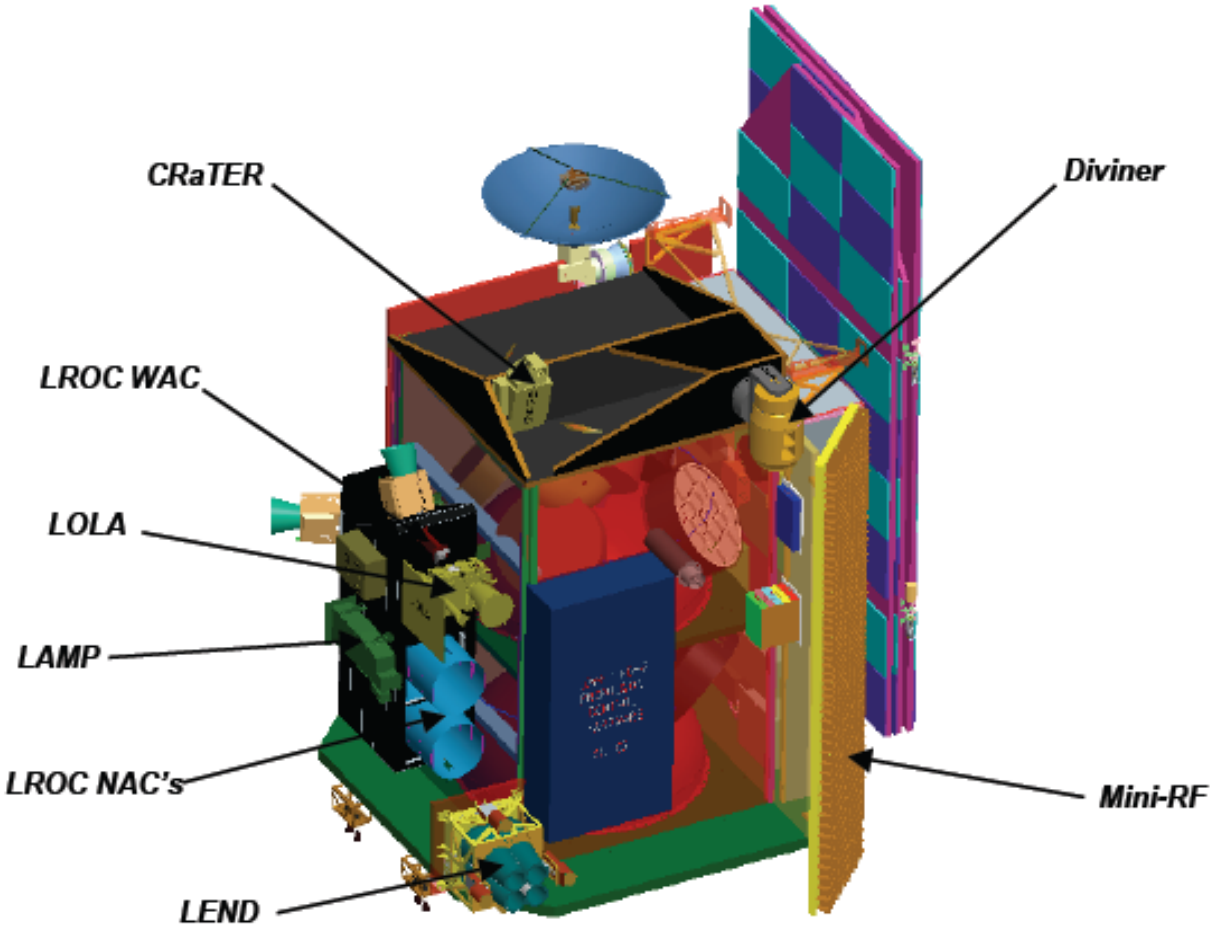
- **Terrain Mapping Camera (TMC)**: 5 meter resolution and a 40 km swath in the panchromatic band and will be used to produce a high-res map of the Moon. (Indian)
- **Hyper Spectral Imager (HySI)**: mineralogical mapping in the 400-900 nm band with a spectral resolution of 15 nm and a spatial resolution of 80 m.
- **Lunar Laser Ranging Instrument (LLRI)**: determine surface topography.
- **X-ray fluorescence spectrometer**:
  - Imaging X-ray Spectrometer (CIXS) covering 1-10 keV with a ground resolution of 10 km; will map Si, Al, Mg, Ca, Fe, and Ti at the surface
  - High Energy X-ray/gamma ray spectrometer (HEX) for 10-200 keV measurements with ground resolution of about 20 km; will measure K, U, Th, Pb(210), Rn(222)
  - Solar X-ray Monitor (SXM) to detect solar flux in the 2-10 keV range. SXM will monitor the solar flux to normalize the results of CIXS and HEX.
- **Sub-keV Atom Reflecting Analyzer (SARA)**: will map composition using low energy neutral atoms sputtered from the surface.
- **Moon Mineralogy Mapper (M3)**: imaging spectrometer designed to map the surface mineral composition.
- A **near-infrared spectrometer (SIR-2)**: will also map the mineral composition using an infrared grating spectrometer.
- **Miniature Synthetic Aperture Radar (Mini-SAR)**: will perform radar scattering and imaging investigations at the poles in a search for water ice.

Lunar Reconnaissance Orbiter (LRO)

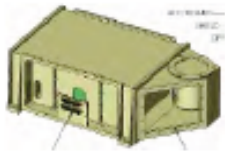
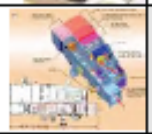
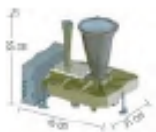
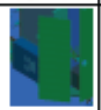
- Launch planned for October, 2008
- Provides knowledge required for safe landing-site selection and in-situ resource utilization.
- Planned: 50 km altitude circular orbit
- Focus on lunar poles

LRO Instrument Payload

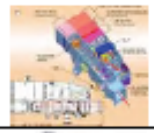
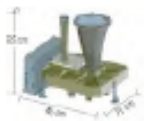
- Payload includes 8 scientific instruments
- Nominal mission is one year
- Extended mission: 6 months at 50 km or several years at high, stable orbit



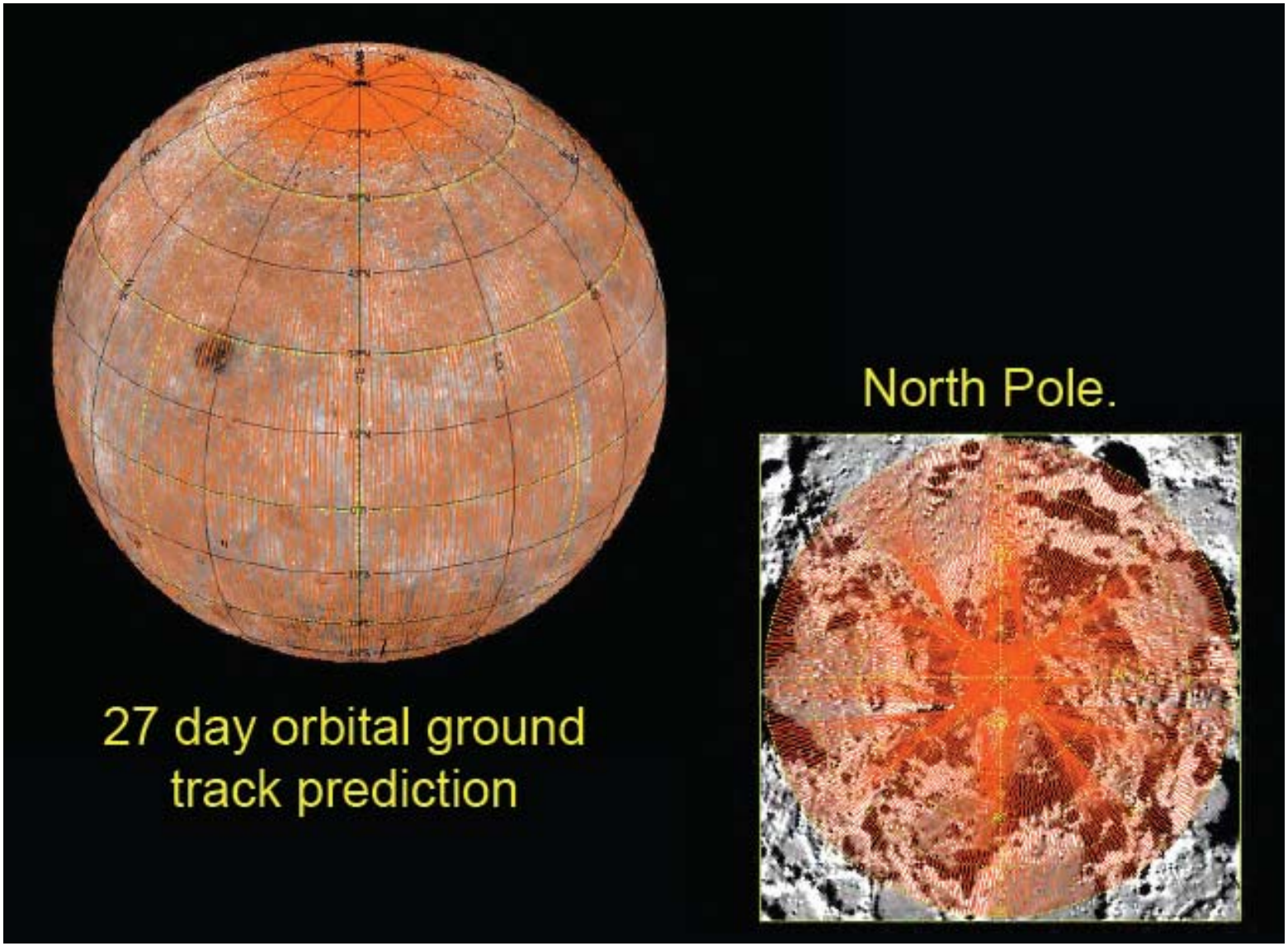
LRO Instrument Suite

Instrument	Navigation/ Landing Site Safety	Locate Resources	Life in Space Environment	New Technology
CRaTER Cosmic Ray Telescope for the Effects of Radiation 			• High Energy Radiation • Radiation effects on human tissue	
DLRE Diviner Lunar Radiometer Experiment 	• Rock abundance	• Temperature • Mineralogy		
LAMP Lyman Alpha Mapping Project 		• Surface Ice • Image Dark Craters		
LEND Lunar Exploration Neutron Detector 		• Subsurface Hydrogen Enhancement • Localization of Hydrogen Enhancement	• Neutron Radiation Environment	
LOLA Lunar Orbiter Laser Altimeter 	• Slopes • Topography/Rock Abundance • Geodesy	• Simulation of Lighting Conditions • Crater Topography • Surface Ice Reflectivity		
LROC Lunar Reconnaissance Orbiter Camera 	• Rock hazards • Small craters	• Polar Illumination Movies • Mineralogy		
Mini-RF *Technology Demonstration* 				• S-band and X-band SAR demonstration

LRO Instrument Suite

INSTRUMENT	Key Data Products	Exploration Benefits	Science Benefits
CRaTER Cosmic Ray Telescope for the Effects of Radiation 	Lunar and deep space radiation environment and tissue equivalent plastic response to radiation	Safe, lighter weight space vehicles. Radiation environment for human presence at the Moon and journeys to Mars and beyond.	Radiation boundary conditions for biological response . Map radiation reflected from lunar surface
DLRE Diviner Lunar Radiometer Experiment 	500 m scale maps of surface temperature, albedo, rock abundance, and ice stability	Measures thermal environment in permanent shadow and permanent light, ice depth map	Source, history, migration and deposition of polar volatiles
LAMP Lyman Alpha Mapping Project 	Maps of frosts and landforms in permanently shadowed regions (PSRs).	Locate potential water-ice on the surface, image shadowed areas, and map potential landing areas in PSRs	
LEND Lunar Exploration Neutron Detector 	Maps of hydrogen in upper 1 m of Moon at 10 km scales, neutron albedo	Locate potential water-ice in lunar soil or concentrations of implanted hydrogen	
LOLA Lunar Orbiter Laser Altimeter 	~25 m scale polar topography at < 10 cm vertical, global topography, surface slopes and roughness	Identify safe landing sites, image shadowed regions, map potential surface ice, improve gravity field model	Global topography and gravity for interior structure and geological evolution
LROC Lunar Reconnaissance Orbiter Camera 	1000's of 50cm/pixel images, and entire Moon at 100m in UV, Visible. Illumination conditions of the poles.	Surface landing hazards and some resource identification including locations of near constant solar illumination	Tectonic, impact and volcanic processes, resource evaluation, and crustal evolution
Mini-RF *Technology Demonstration* 	X and S-band radar imaging and interferometry	Demonstrate new lightweight SAR and communication technologies, locate potential water-ice	Source, history, deposition of polar volatiles

LRO Emphasizes the Lunar Poles



LRO Mission Phases

Launch: October 31, 2008

Minimum Energy Lunar Transfer ~ 4 Days

Lunar Orbit Insertion Sequence, 4 Maneuvers, 2-4 Days

Commissioning Phase, 30 x 216 km Altitude Quasi-Frozen Orbit, Up to 60 Days

Polar Mapping Phase, 50 km Altitude Circular Orbit, At least 1 Year

Nominal End of Mission: February 2010